The Full Color Maxwellian-view Display Based on Holographic Optical Element

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ABSTRACT

A full color Maxwellian-view display based on HOE is proposed. The device can offer observers the information from the mask. The image quality won't be affected when focus on different distance. The HOE with the wavelength multiplexing can reconstruct the full color backlight to get full color image.

1 INTRODUCTION

In the past, the traditional see-through displays are usually combined with augmented reality (AR) function [1]. For traditional case, the half silvered mirror and eyepiece were employed to achieve the see-through function [1, 2]. However due to these components will make the AR system bulky and heavy. In the recent research, the holographic optical element (HOE) is usually used to replace these components to offer image for see-through display [3-5]. The Maxwellian-view display is a special see-through display, the image of the Maxwellian-view display project onto the retina independent of the diopter of the pupil of eyes [6]. Thus, the retina image quality can't be affected when observer focus on different distance. General Maxwellian-view display is based on geometrical optics, using the lens to generate the converging wave. Therefore,

In the previous works, a monochrome static information by a transparent film [7] and dynamic information by the LCD panel which is designed [8] were proposed.

In this study, a full color Maxwellian-view display based on HOE is proposed. The full color HOE is recorded by wavelength multiplexing, the recording parameters are determined, the HOE is attached on waveguide element to achieve the full color display, and the image quality can't be affected when focus on different distance.

2 EXPERIMENT

As shown in Fig.1, the schematic diagram of basic function of the Maxwellian-view display based on HOE. A collimated beam is coupled into the waveguide with the information of the mask under conditions of the total internal reflection (TIR), and then a converged spherical wave will be diffracted when the collimated beam probes the HOE. And then the information of the mask will be projected on the retina. Since the information of the mask is projected on the retina, the image quality will not be affected when the observer focus on different distance. In this study, a glassy trapezoidal waveguide is chosen. The angle of this waveguide is 17.7°. The detailed information of the waveguide is shown as Fig. 2.

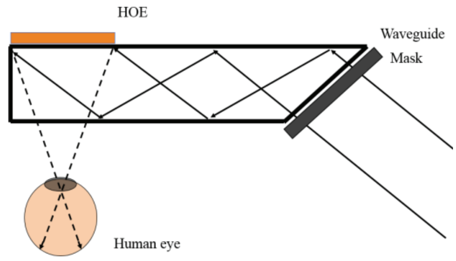


Fig. 1 The maxwellian-view display based on HOE

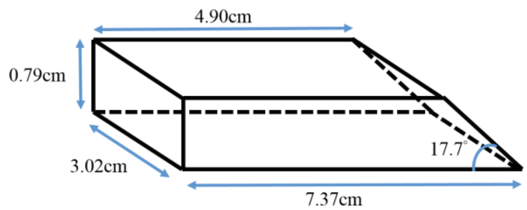


Fig. 2 The information of the trapezoidal waveguide

In order to achieve the full color display, the HOE with wavelength multiplexing is a must. The recording process for generating the HOE device is shown as Fig.3. In this system, the He-Ne laser (633nm), DPSS laser (532nm), and single mode laser (457 nm) have be used, the white laser composed of the three laser by mirror and two dichroic mirror (DM). First, an unexposed hologram attached on the glassy waveguide. the half-wave plate (HWP) and polarized beam splitter (PBS) be used to generate two S-polarized. And then, these beam are turned into collimation wave by the spatial filter (SF) and collimating lens (CL). One collimation wave coupled into the waveguide and its angle of incident fit the conditions of the TIR, another collimation wave is turned into converged wave by propagating through the lens which focus 10cm. The hologram recorded the interference fringe which was generated by the collimation wave and the converged spherical wave.

The Fig. 4 show the observation system. A collimating wave coupled into the waveguide with the information of the mask under the condition of the TIR. The camera focus at the three different distances behind the waveguide, respectively, it is 50 cm, 100 cm, 150 cm. In this study, the mask is chosen, the mask information as shown in Fig. 5. In the Fig. 5 the black part of the mask is opaque, and the white part of the mask is transparent.

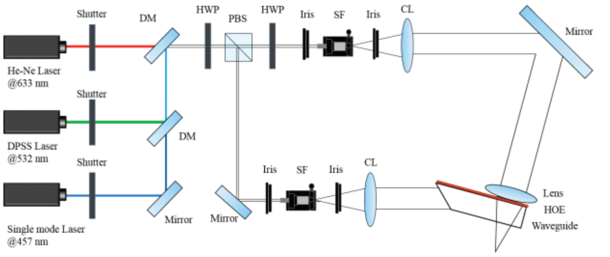


Fig. 3 the system for generating the HOE device. DM: dichroic mirror, HWP: half-wave plate, PBS: polarized beam splitter, SF: spatial filter, CL: collimating lens.

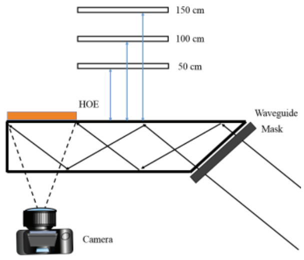


Fig. 4 The recording system. The camera focus at 50 cm, 100 cm, 150 cm behind the waveguide, respectively.

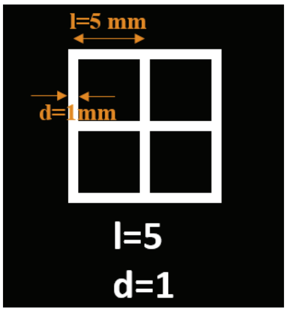
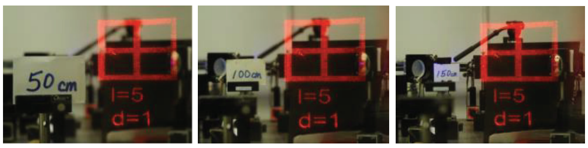


Fig. 5 The mask used in this study.

3 RESULTS

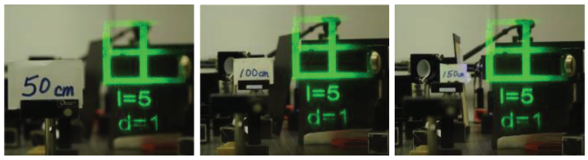
3.1 Image Quality

The image quality from this device for different backlight is shown as Fig. 6 to Fig. 9. From Fig. 6 to Fig. 9, the camera focuses at the three different distances behind the waveguide, respectively, it is 50 cm, 100 cm, 150 cm. With the different backlight, the full color image can be observed and the image quality won't be affected when observers focus on different distance, because the converged spherical wave focus on the center of the crystal of the human eye to project onto the retina.



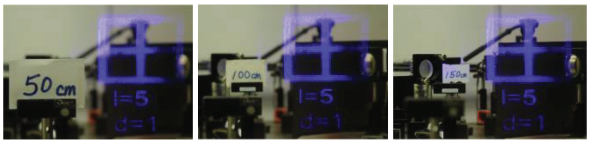
(a) (b) (c)

Fig. 6 The retinal images generated by the Maxwellian-view display with red laser backlight, the camera focus at (a) 50cm, (b) 100cm, (c) 150cm.



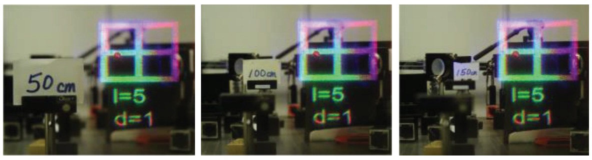
(a) (b) (c)

Fig. 7 The retinal images generated by the Maxwellian-view display with green laser backlight, the camera focus at (a) 50cm, (b) 100cm, (c) 150cm.



(a) (b) (c)

Fig. 8 The retinal images generated by the Maxwellian-view display with blue laser backlight, the camera focus at (a) 50cm, (b) 100cm, (c) 150cm.



(a) (b) (c)

Fig. 9 The retinal images generated by the Maxwellian-view display with white laser backlight which composed of the red, green, blue laser, the camera focus at (a) 50cm, (b) 100cm, (c) 150cm.

3.2 Field of View (FOV)

In order to measure the viewing angle in vertical and horizontal, along depth of field (DOF) camera and a screen located at 50cm in front of camera were used to analysis viewing angle. The maximum of the width and length of the output image on the screen and the distance from the viewer to the screen are used to calculate the FOV.

$$\theta = \tan^{-1}\frac{w}{l} \cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

In the eq. 1, w represents the horizontal or vertical height of the image on the screen, and l represents the distance from the viewer to the screen. In this step, the observation system as shown in Fig. 4, replace the mask to a 3mm×3mm per grid mask be used to measure as shown in Fig.10. The different backlight with the grid mask is shown as Fig. 11.

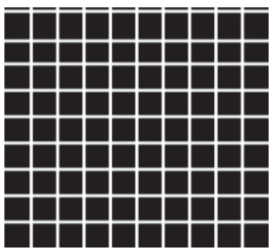
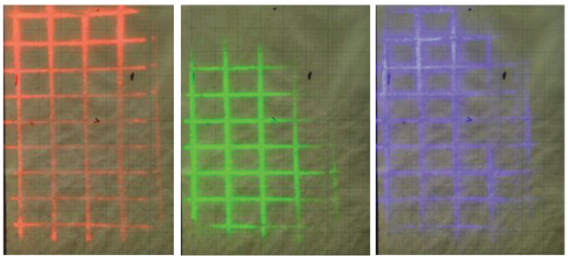


Fig. 10 The information of the grid mask, 3mm×3mm per unit grid



(a) (b) (c)

Fig. 11 The retinal images generated by the Maxwellian-view display with (a) red, (b) green, (c) blue laser backlight

The FOV with different backlight is calculated at Table 1. From Table 1, the maximum FOV can achieve full color is 9.64°×10.32° (horizontal × vertical)

Table 1 The FOV with the different backlight

	Red laser	Green laser	Blue laser
horizontal	9.64°	9.64°	9.64°
vertical	14.62°	10.32°	13.76°

3.3 The MTF of Retinal image

Using the USAF test target test the MTF of retinal image, the observation system as shown in Fig. 4, replace the mask to USAF test target. The information of the USAF test target as show as Fig. 12. The different backlight with the USAF test target is shown as Fig. 13. From Fig. 13, the G1L6 can be overserved by human eyes. The corresponding value in Table 2 is 3.56 lp/mm.

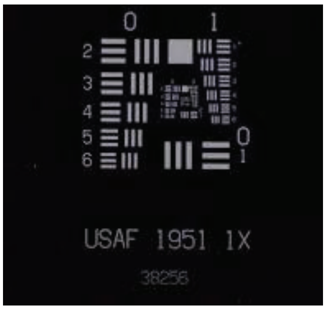
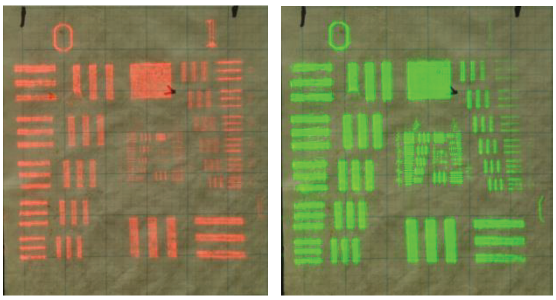
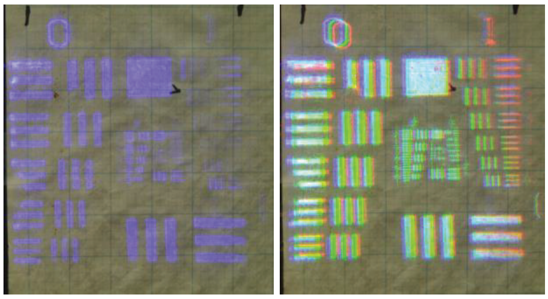


Fig. 12 The information of the USAF test target



(a) (b)



(c) (d)

Fig. 13 The USAF test target generated by the Maxwellian-view display with (a) red, (b) green, (c) blue (d) white laser backlight

Table 2. Number of line pairs/mm in USAF test target

Number of line pairs/mm in USAF Resolving Power Test Target 1951					
	Group Number				
Element	0	1	2	3	4
1	1.00	2.00	4.00	8.00	16.00
2	1.12	2.24	4.49	8.98	17.95
3	1.26	2.52	5.04	10.10	20.16
4	1.41	2.83	5.66	11.30	22.62
5	1.59	3.17	6.35	12.70	25.39
6	1.78	3.56	7.13	14.30	28.50

4 DISCUSSION

In this study, a full color Maxwellian-view display based on the HOE is proposed. But this system has some defect need to improve. First, when the white backlight probes the HOE with the wavelength multiplexing, the RGB diffraction efficiency uneven leads to the full color FOV become smaller. Second, the RGB of the full color image is a little staggered.

To solve the first problem, adjust the parameters of the exposure and increase the uniformity of object wave and reference wave can effectively improve the problem, the second problem was caused by the lens. The lens which record on the HOE have dispersion aberration. It can be considered that changing a non-dispersion aberration lens can improve this problem.

5 CONCLUSIONS

In this study, the HOE with the wavelength multiplexing is success and the full color Maxwellian-view display based on the HOE is proposed. Because the converged spherical wave focus on the center of the crystal of the human eye to project onto the retina, this system can provide a full color clear image no matter where the observer is focusing when the mask is placed in front of the waveguide. The FOV of the full color image achieve 9.64° in horizontal direction and 10.32° in vertical direction. The G1L6 can be overserved by human eyes, the MTF of this system is 3.56 lp/mm.

In the future work, the computer generated hologram (CGH) will be combined with this system to provide a dynamic information or a 3D information. Therefore, the light tracking system will be combined with the Maxwellian-view, the Maxewllian-view can be moved the ray convergence point according to the eye movement.

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